# Shallow-to-Deep Convective Transition during the Onset of Madden-Julian Oscillation

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## 1. Introduction

One intriguing feature of the MJO initiation is the transition from shallow cumulus to widespread deep convection (SDT). This study examines the SDT processes at the onset of ~90 MJOs over the Indian Ocean as sampled by TRMM. Congestus have been considered to play key roles in moistening the midtroposphere and preconditioning the atmosphere to support the onset of MJO deep convection ("discharge-recharge" theory). SDT typically occurs in 10-20 days following this mechanism. However, new observational and modeling studies (based on DYNAMO field campaign) report a shorter time scale of SDT (3-7 days) and question the efficiency of congestus moistening in such a shortened time scale. These DYNAMO-based studies propose that large-scale mechanisms (e.g., uplifting) may play important roles in addition to conguestus moistening during short SDT events. This study addresses the SDT time scale problem and explores potential factors impacting the SDT.

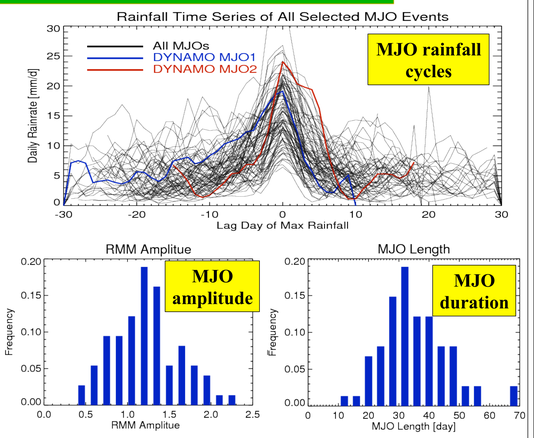
## 2. Data and Methodology

### a. MJO events over the Indian Ocean

**A "Full" MJO Cycle**

1. Define by Real-time Multivariate MJO (RMM) index (WH 2004);
2. At least six RMM phases (6-7-8-1-2-3), e.g., suppressed, building, and active phases over the IO;
3. Maximum regional (central IO) mean rainrate > 5 mm/day.

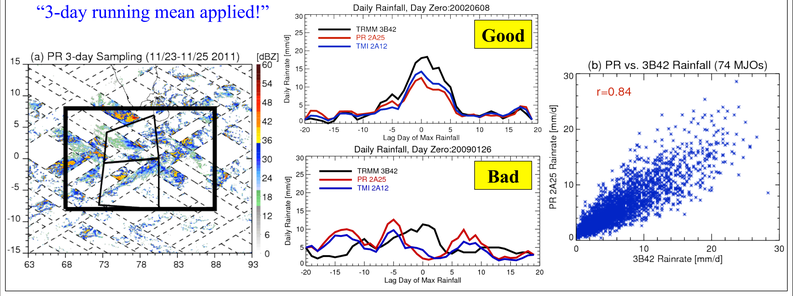
**"92 MJOs in 1998-2013"**




### b. Can TRMM Resolve individual MJO Evolution?

**80% (74) MJOs well sampled, i.e., PR rainfall consistent with 3-hourly 3B42.**

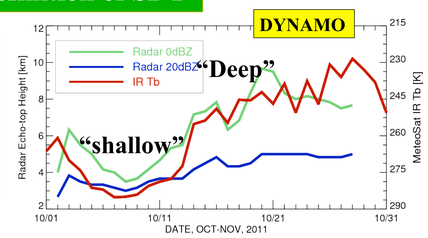
"3-day running mean applied!"

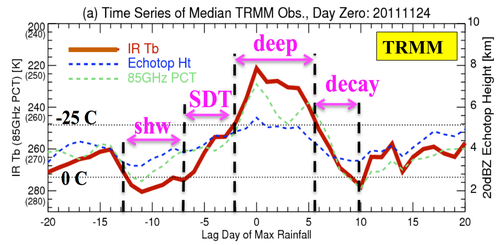



## 3. Spectrum of SDT Time Scales

### a. Definition of SDT

**Shipborne and Satellite observations during DYNAMO** suggest **0dBZ echo-top height** and **IR Tb** better represent SDT variability thus good SDT metrics




"Cloudtops (IR) over convective rain areas (by PR)!"

*(Similar to Kikuchi and Takayabu 2004)*

"Shallow (**shw**): > 0 C (~5km)

**Deep**: < -25 C (~9 km)

Shallow-to-deep (**SDT**): 0 C to -25 C

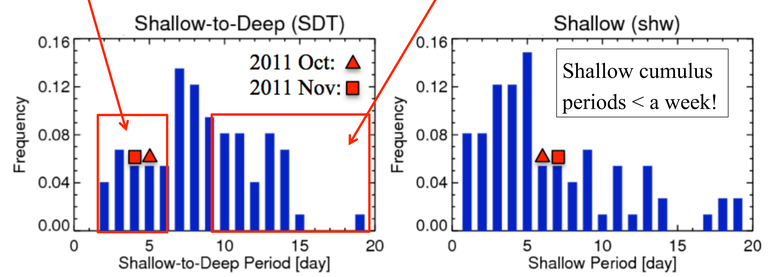
**Decay**: > -25 C after deep

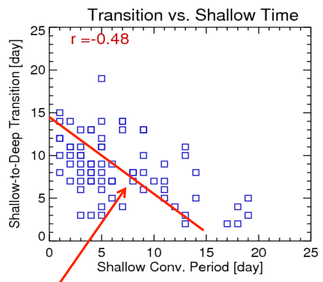
### b. Time Scales of Various Convectie Periods?

~25% of examined MJOs experience rapid SDT (< 7 days) including the two DYNAMO MJOs.

**"Two different SDT processes?"**

Nearly 40% MJOs have SDT established in 10-20 days, a typical time scale of sufficient moistening by congestus in discharge-recharge!

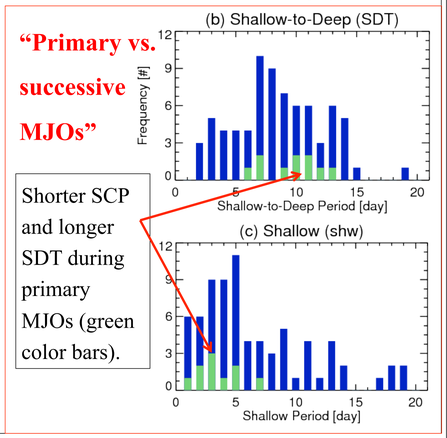



SDT timescale is negatively correlated with the shallow period (SCP) prior to the SDT; long SCP may signal rapid SDT.

**"Primary vs. successive MJOs"**

Shorter SCP and longer SDT during primary MJOs (green color bars).

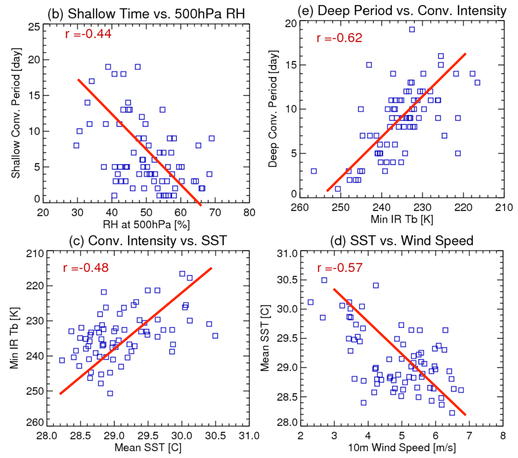



## 4. Impacting Factors

"(a) SDT is negatively correlated to shallow period, but weakly correlated with any single environmental variable (e.g. SST). "

"(b) The drier the middle troposphere the longer the suppressed period."

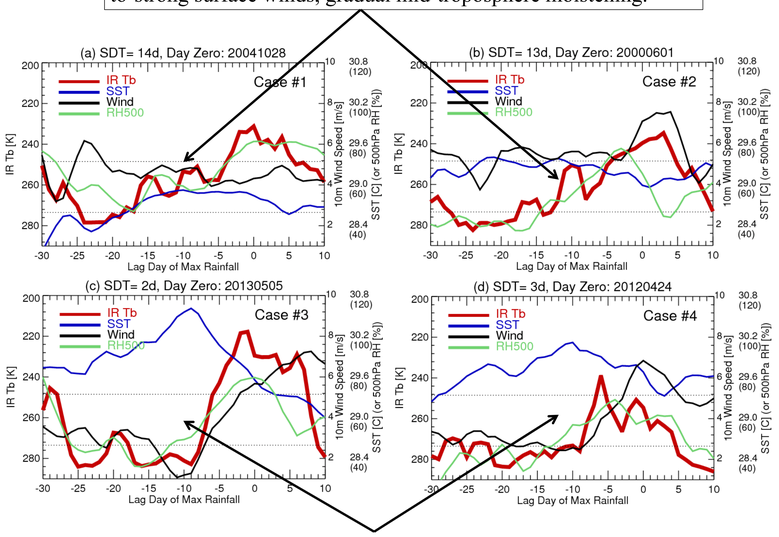
"(c) MJO conv. depth is largely related to SST, which is negatively correlated to low-level wind speed (d)."




"In addition, SDT have weak relation with duration and magnitude of individual MJOs, convective depth, and even rainfall (not shown)."

## 5. Extreme Cases

**Gradual SDT** (deepening in 2 weeks): moderate SST, moderate-to-strong surface winds, gradual mid-troposphere moistening.




**Rapid SDT** (deepening in 2-3 days): extended suppressed periods, persistent high SST, weak surface winds, shortened mid-troposphere moistening.

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